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Tool with tool body and protective layer system*Handwritten:* ~~This description has an Appendix A.~~

The present invention is directed on a tool with a tool body and a wear resistant layer system, wherein the layer system

5 comprises at least one layer of MeX, wherein

- Me comprises titanium and aluminum,
- X is at least one of nitrogen and of carbon.

Definition:

- The term Q_I is defined as the ratio of the diffraction intensities $I(200)$ to $I(111)$, assigned respectively to the (200) and (111) plains in the X ray diffraction of a material using the θ - 2θ method. Thus, there is valid $Q_I = I(200)/I(111)$. The intensity values were measured with the following equipment and with the following settings:

15 Siemens Diffractometer D500

Power: Operating voltage: 30 kV

Operating current: 25 mA

Aperture Diaphragms: Diaphragm position I: 1°

Diaphragm position II: 0.1°

20 Detector Diaphragm: Soller slit

Time constant: 4 s

2θ angular speed: 0.05°/min

Radiation: Cu-Kα (0.15406 nm)

When we refer to "measured according to MS" we refer to this
25 equipment and to these settings. Thereby, all quantitative re-

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sults for Q_i , and I throughout this application have been measured by MS.

• We understand by "tool body" the uncoated tool.

• We understand under "hard material" a material with which

5 tools which are mechanically and thermally highly loaded in operation are coated for wear resistance. Preferred examples of such materials are referred to below as MeX materials.

It is well-known in the tool-protecting art to provide wear resistant layer systems which comprise at least one layer of a

10 hard material, as defined by MeX.

The present invention has the object of significantly improving the lifetime of such tools. This is resolved by selecting for said at least one layer a Q_i value, for which there is valid

$$Q_i \geq 1$$

15 and wherein the tool body is made of high speed steel (HSS) or of cemented carbide, whereby said tool is not a solid carbide end mill or a solid carbide ball nose mill. Further, the value of $I(200)$ is higher by a factor of at least 20 than the intensity noise average level as measured according to MS.

20 According to the present invention it has been recognised that the Q_i values as specified lead to an astonishingly high improvement of wear resistance, and thus of lifetime of a tool, if such a tool is of the kind as specified.

Up to now, application of a wear resistant layer systems of MeX 25 hard material was done irrespective of interaction between tool body material and the mechanical and thermal load the tool is

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subjected to in operation. The present invention thus resides on the fact that it has been recognised that an astonishing improvement of wear resistance is realised when selectively combining the specified Q_i value with the specified kind of tools, thereby realising a value of $I(200)$ higher by a factor of at least 20 than the average noise intensity level, both measured with MS.

With respect to inventively coating cemented carbide tool bodies, it has further been recognised that a significant improvement in lifetime is reached if such cemented carbide tools are inserts, drills or gear cutting tools, as e.g. hobs or shaper cutters, whereby the improvement is especially pronounced for such inserts or drills.

The inventively reached improvement is even increased if Q_i is selected to be at least 2, and an even further improvement is realised by selecting Q_i to be at least 5. The largest improvements are reached if Q_i is at least 10. It must be stated that Q_i may increase towards infinite, if the layer material is realised with a unique crystal orientation according to a diffraction intensity $I(200)$ at a vanishing diffraction intensity $I(111)$. Therefore, there is not set any upper limit for Q_i , which is only set by practicability.

As is known to the skilled artisan, there exists a correlation between hardness of a layer and stress therein. The higher the stress, the higher the hardness.

Nevertheless, with rising stress, the adhesion to the tool body tends to diminish. For the tool according to the present invention, a high adhesion is rather more important than the highest possible hardness. Therefore, the stress in the MeX layer is

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advantageously selected rather at the lower end of the stress range given below.

These considerations limit in practice the Q_i value exploitable.

- 5 In a preferred embodiment of the inventive tool, the MeX material of the tool is titanium aluminum nitride, titanium aluminum carbonitride or titanium aluminum boron nitride, whereby the two materials first mentioned are today preferred over titanium aluminum boron nitride.
- 10 In a further form of realisation of the inventive tool, Me of the layer material MeX may additionally comprise at least one of the elements boron, zirconium, hafnium, yttrium, silicon, tungsten, chromium, whereby, out of this group, it is preferred to use yttrium and/or silicon and/or boron. Such additional element to titanium and aluminum is introduced in the layer material, preferably with a content i , for which there is valid
- 15

$$0.05 \text{ at.\%} \leq i \leq 60 \text{ at.\%},$$

taken Me as 100 at%.

- A still further improvement in all different embodiments of the 20 at least one MeX layer is reached by introducing an additional layer of titanium nitride between the MeX layer and the tool body with a thickness d , for which there is valid

$$0.05 \mu\text{m} \leq d \leq 5 \mu\text{m}.$$

- In view of the general object of the present invention, which 25 is to propose the inventive tool to be manufacturable at lowest possible costs and thus most economically, there is further

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proposed that the tool has only one MeX material layer and the additional layer which is deposited between the MeX layer and the tool body.

Further, the stress σ in the MeX is preferably selected to be

5 1 GPa \leq σ \leq 4 GPa, thereby most preferably

within the range

1.5 GPa \leq σ \leq 2.5 GPa.

The content x of titanium in the Me component of the MeX layer is preferably selected to be

10 70 at $\% \geq x \geq 40$ at $\%$, thereby in a further

preferred embodiment within the range

65 at $\% \geq x \geq 55$ at $\%$.

On the other hand, the content y of aluminum in the Me component of the MeX material is preferably selected to be

15 30 at $\% \leq y \leq 60$ at $\%$, in a further preferred

embodiment even to be

35 at $\% \leq y \leq 45$ at $\%$.

In a still further preferred embodiment, both these ranges, i.e. with respect to titanium and with respect to aluminum are 20 fulfilled.

The deposition, especially of the MeX layer, may be done by any known vacuum deposition technique, especially by a reactive PVD coating technique, as e.g. r active cathodic arc evaporation or

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reactive sputtering. By appropriately controlling the process parameters, which influence the growth of the coating, the inventively exploited Q_i range is realised.

To achieve excellent and reproducible adhesion of the layers to
5 the tool body a plasma etching technology was used, as a pre-
paratory step, based on an Argon plasma as described in Appen-
dix A, which document is integrated to this description by ref-
erence, with respect to such etching and subsequent coating.

10 This document accords with the US application No. 08/710 095 of
the same inventor (two inventors!) and applicant as the present
application.

John P.2
Examples 1

An arc ion plating apparatus using magnetically controlled arc
sources as described in Appendix A was used operated as shown
15 in table 1 to deposit the MeX layer as also stated in table 1
on cemented carbide inserts. The thickness of the MeX layer de-
posited was always 5 μm . Thereby, in the samples Nr. 1 to 7,
the inventively stated Q_i values where realised, whereas, for
comparison, in the samples number 8 to 12 this condition was
20 not fulfilled. The $I(200)$ value was always significantly larger
than 20 times the noise average value, measured according to
MS. The coated inserts were used for milling under the follow-
ing conditions to find the milling distance attainable up to
delamination. The resulting milling distance according to the
25 lifetime of such tools is also shown in table 1.

Test cutting conditions:

- Material being cut: SKD 61 (HRC45)

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- Cutting speed: 100 m/min

- Feed speed: 0.1 m/edge

- Depth of cut: 2 mm

The shape of the inserts coated and tested was in accordance

5 with SEE 42 TN (G9).

It is clearly recognisable from table 1 that the inserts, coated according to the present invention, are significantly more protected against delamination than the inserts coated according to the comparison conditions.

10 Further, the result of sample 7 clearly shows that here the stress and thus hardness of the layer was reduced, leading to lower cutting distance than would be expected for a high Q_c of 22.5, still fulfilling the stress-requirements as defined above.

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(Table 1)

Sample No.	Coating Conditions		Layer	x	y	$\frac{Q_1 - I(200)}{I(111)}$	Residual Stress gpa	Achievable Cutting Dis- tance (m) (distance till delami- nation)	Remarks
	Bias Voltage N, pressure (mbar)	ARC Current (A)							
Present									
1	60	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	1.5	5.2	2.2m (2.1m)
2	60	8.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	6.7	4.8	2.8m (2.5m)
3	40	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	8.1	4.2	8.8m (8.5m) face lapping
Invention									
4	40	3.0×10^2	150	(Ti ₁ Al ₁)N	0.4	0.6	10.2	3.9	3.8m (3.5m)
5	40	0.5×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	6.0	5.8	2.0m (1.7m)
6	30	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	15.4	2.5	4.2m (4.0m)
7	20	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	22.5	1.2	3.3m (3.3m)
Comparison									
8	60	0.5×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	0.8	6.1	1.0m (0.8m)
9	100	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	0.7	5.5	0.9m (0.9m)
10	100	3.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	0.9	4.8	0.8m (0.7m)
11	150	2.0×10^2	150	(Ti ₁ Al ₁)N	0.5	0.5	0.2	7.2	0.1m (0.1m)
12	100	0.5×10^2	150	(Ti ₁ Al ₁)N	0.4	0.6	0.1	6.8	0.2m (0.1m)

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Examples 2:

The apparatus as used for coating according to Example 1 was also used for coating the samples Nr. 13 to 22 of table 2. The thickness of the overall coating was again 5 μm . It may be seen 5 that in addition to the coating according to Example 1 there was applied an interlayer of titanium nitride between the MeX layer and the tool body and an outermost layer of the respective material as stated in table 2. The condition with respect to $I(200)$ and average noise level, measured according to MS was 10 largely fulfilled.

It may be noted that provision of the interlayer between the MeX layer and the tool body already resulted in a further improvement. An additional improvement was realised by providing an outermost layer of one of the materials titanium carbonitride, titanium aluminum oxinitride and especially with an outermost layer of aluminum oxide. Again, it may be seen that by realising the inventively stated Q_r values with respect to the comparison samples number 19 to 22, a significant improvement is realised.

20 The outermost layer of aluminum oxide of 0.5 μm thickness, was formed by plasma CVD.

The coated inserts of cemented carbide were tested under the same cutting conditions as those of Example 1. Q_r was measured according to MS.

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(Tabelle 2)

Sample No.	Inter-layer (μm)	TiAl Layer	x	y	Outermost Layer	$\frac{Q_t}{I(200)} / \frac{I(111)}{I(111)}$	Attainable Cutting Distance (m) (distance till delamination)
Present	13 (0.4 μm)	(Ti _x Al _y)N (4.6 μm)	0.5	0.5	-	1.5	4.5m (4.2)
	14 (0.4 μm)	(Ti _x Al _y)N (4.1 μm)	0.5	0.5	TiCN (0.5 μm)	7.2	7.8 (7.6m)
Invention	15 (0.4 μm)	(Ti _x Al _y)N (4.4 μm)	0.5	0.5	TiCN (0.5 μm)	6.8	6.0m (5.5m)
	16 (0.4 μm)	(Ti _x Al _y)N (4.1 μm)	0.5	0.5	(TiAl)NO (0.5 μm)	5.2	6.2m (6.0m)
17	TiCN (0.4 μm)	(Ti _x Al _y)N (4.1 μm)	0.5	0.5	Al ₂ O ₃ (0.5 μm)	12.5	10.1m (9.8m)
	TiN (0.4 μm)	(Ti _x Al _y)N (4.1 μm)	0.5	0.5	Al ₂ O ₃ (0.5 μm)	7.0	9.8m (9.5m)
Comparison	18 (0.4 μm)	(Ti _x Al _y)N (4.1 μm)	0.5	0.5	Al ₂ O ₃ (0.5 μm)	0.8	1.5m (1.2m)
	19 TiN	(Ti _x Al _y)N	0.5	0.5	-	0.8	1.5m (1.2m)
	20 TiN	(Ti _x Al _y)N	0.5	0.5	TiCN	0.8	1.9m (1.5m)
	21 TiN	(Ti _x Al _y)N	0.5	0.5	TiCN	0.7	1.8m (1.5m)
22	TiN	(Ti _x Al _y)N	0.5	0.5	(TiAl)NO	0.1	0.6m (0.4m)

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Example 3:

Again, cemented carbide inserts were coated with the apparatus of Example 1 with the MeX layer as stated in table 3, still fulfilling the Q_i conditions as inventively stated and, by far, 5 the condition of I(200) with respect to average noise level, measured according to MS. Thereby, there was introduced one of zirconium, hafnium, yttrium, silicon and chromium, with the amount as stated above, into Me.

The coated inserts were kept in an air oven at 750°C for 30 10 min. for oxidation. Thereafter, the resulting thickness of the oxide layer was measured. These results are also shown in table 3. For comparison, inserts coated inventively with different Me compounds of the MeX material were equally tested. It becomes 15 evident that by adding any of the elements according to samples 23 to 32 to Me, the thickness of the resulting oxide film is significantly reduced. With respect to oxidation the best results were realised by adding silicon or yttrium.

It must be pointed out, that it is known to the skilled artisan, that for the MeX material wear resistant layers there is 20 valid: The better the oxidation resistance and thus the thinner the resulting oxide film, the better the cutting performance.

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(Table 3)

	Sample No.	Layer Composition	w	x	y	z	Thickness of Oxide Film (μm)
	23	(Ti,Al,Y,N)		0.48	0.5	0.02	0.7
	24	(Ti,Al,Cr,N)		0.48	0.5	0.02	0.9
	25	(Ti,Al,Zr,N)		0.48	0.5	0.02	0.7
	26	(Ti,Al,Y,N)		0.25	0.5	0.25	0.1
Present	27	(Ti,Al,Zr,N)		0.25	0.5	0.25	0.5
	28	(Ti,Al,W,N)		0.4	0.5	0.1	0.8
	29	(Ti,Al,Si,N)		0.4	0.5	0.1	0.1
	30	(Ti,Al,Si,N)		0.48	0.5	0.02	0.2
	31	(Ti,Al,Hf,N)		0.4	0.5	0.1	0.9
	32	(Ti,Al,Y,Si,N)	0.1	0.3	0.5	0.1	0.05
	33	(Ti,Al,N)		0.4	0.6		1.8
	34	(Ti,Al,Nb,N)		0.4	0.5	0.1	2.5
Comparison	35	(Ti,Al,Ta,N)		0.4	0.5	0.1	3.3

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Example 4:

An apparatus and a coating method as used for the samples of Example 1 was again used.

HSS drills with a diameter of 6 mm were coated with a 4.5 μm

s MeX and a TiN interlayer was provided between the MeX layer and the tool body, with a thickness of 0.1 μm . The test condition were:

Tool: HSS twist drill, dia. 6 mm

Material: DIN 1.2080 (AISI D3)

10 Cutting parameters: $v_c = 35 \text{ m/min}$

$f = 0.12 \text{ mm/rev.}$

15 mm deep blind holes with coolant.

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(Table 4)

	Bias Voltage (-V)	N ₂ Pressure (mbar)	Arc current (A)	Inter-layer	layer	x	y	z	Q ₁	Residual Stress (GPa)	Number of drilled holes
Present Invention	36	40	3.0 x 10 ⁻³	200	TIN	(Ti,Al _x)N	0.6	0.4	5.4	2.1	210
	37	40	3.0 x 10 ⁻³	200	TIN	(Ti,Al _x)N	0.58	0.4	0.02	3.8	2.3
	38	150	1.0 x 10 ⁻³	200	TIN	(Ti,Al _x)N	0.6	0.4	0.03	4.5	10
Comparison	39	150	1.0 x 10 ⁻³	200	TIN	(Ti,Al _x)N	0.58	0.4	0.02	0.1	38

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The lifetime of the tool was determined by the number of holes which could be drilled before failure of the drill.

The results of the inventively coated drills are shown as samples No. 36 and 37 in Table 4, the samples No. 38 and 39 again show comparison samples. Again, I(200) exceeded 20 times intensity average noise level by far, for samples 36, 37, as measured by MS.

Example 5:

Again, the apparatus and method as mentioned for Example 1 was used for coating HSS roughing mills with a diameter of 12 mm with a 4.5 μm MeX layer. There was provided a titanium nitride interlayer with a thickness of 0.1 μm between the MeX layer and the tool body. The test conditions were:

15 Tool: HSS roughing mill, dia. 12 mm

$z = 4$

Material: AISI H13 (DIN 1.2344)

640 N/mm²

Cutting parameters: $v_c = 47.8 \text{ m/min}$

20 $f_t = 0.07 \text{ mm}$

$a_p = 18 \text{ mm}$

$a_e = 6 \text{ mm}$

climb milling, dry.

The HSS roughing mill was used until an average width of flank wear of 0.2 mm was obtained.

Sample No. 40 in Table No. 5 shows the results of the inventively coated tool, sample 41 is again for comparison. Again,

5 I(200) of sample Nr. 40 fulfilled the condition with respect to
noise, as measured by MS.

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(Table 5)

	Bias Voltage (-V)	N ₂ Pressure (mbar)	Arc current (A)	Inter-layer	γ	η	Residual Stress (GPa)	Cutting distance (m)	
Present	40	3.0×10^{-7}	200	7'N 0.1 μ m	$(T_1 Al_7)N$	0.6	0.4	5.4	2.1
Invention	150	1.0×10^{-7}	200	7'N 0.1 μ m	$(T_1 Al_7)N$	0.6	0.4	0.03	4.5
Comparison								1m (chipping and peeling off)	

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Example 6:

Again, the apparatus and coating method according to Example 1 was used. Solid carbide end mills with a diameter of 10 mm with 6 teeth were coated with a $3.0 \mu\text{m}$ MeX layer. There was provided 5 a titanium nitride interlayer with a thickness of $0.08 \mu\text{m}$ between the MeX and the tool body. Test conditions for the end mills were:

Tool: Solid carbide end mill, dia. 10 mm

$z = 6$

10 Material: AISI D2 (DIN 1.2379)

60 HRC

Cutting parameters: $v_c = 20 \text{ m/min}$

$f_t = 0.031 \text{ mm}$

$a_p = 15 \text{ mm}$

15 $a_e = 1 \text{ mm}$

Climb milling, dry

The solid carbide end mills were used until an average width of flank wear of 0.20 mm was obtained. It is to be noted that solid carbide end mills do not belong to that group of tool 20 which is inventively coated with a hard material layer having $Q_i \geq 1$. From the result in Table 6 it may clearly be seen that for this kind of tools $Q_i > 1$ does not lead to an improvement. Again, the $I(200)$ to noise condition, measured with MS, was fulfilled for sample No. 42, for sample No. 43 the $I(111)$ to 25 noise condition was fulfilled.

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(Table 6)

	Bias Voltage (-V)	N. Pressure (mbar)	Arc current (A)	inter-layer	x	y	Q ₁	Residual Stress (GPa)	Cutting distance (m)
Present Invention	42	40	3.0×10^{-3}	200	TiN	$(Ti,Al)_N$	0.6	0.4	5.0
Comparison	43	150	1.0×10^{-3}	200	TiN	$(Ti,Al)_N$	0.6	0.4	4.7
									12m

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Example 7:

Again, an apparatus and method as used for the samples of Example 1 were used.

5 Solid carbide drills with a diameter of 11.8 mm were coated with a 4.5 μm MeX layer. There was provided a TiN interlayer between the MeX layer and the tool body.

Test conditions:

Tool: Solid carbide drill, diam. 11.8 mm

Workpiece: Cast iron GG25

10 Machining conditions: $v_c = 110 \text{ m/min}$

$f = 0.4 \text{ mm/rev.}$

Blind hole 3 x diam.

No coolant

15 The solid carbide drills were used until a maximum width of flank wear of 0.8 mm was obtained. The I(200) to noise condition was again fulfilled, measured with MS.

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(Table 7)

	Bias Voltage (-V)	N ₂ pressure (mbar)	Arc current (A)	Inter-layer	layer	x	y	Q ₁	Residual stress (GPa)	Drilling distance (m)
Present Invention	44	40	3.0×10^{-7}	200	TiN 0.1 μm	(Ti _x Al _y)N	0.6	0.4	2.1	950
Comparison	45	150	1.0×10^{-3}	200	TiN 0.1 μm	(Ti _x Al _y)N	0.6	0.4	0.03	4.5
										48.5m

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Example 8:

Again, the apparatus and method as stated in Example 1 were used.

Cemented carbide inserts for turning with a shape in accordance with CNGP432 were coated with a 4.8 μm MeX layer. There was provided a TiN interlayer with a thickness of 0.12 μm between the MeX layer and the tool body. The test conditions were:

Tool: Carbide insert (CNGP432)

Material: DIN 1.4306 (X2CrNi 1911)

Cutting parameters: $v_c = 244 \text{ m/min}$

$f = 0.22 \text{ mm/rev.}$

$a_p = 1.5 \text{ mm}$

with emulsion

The tool life was evaluated in minutes. The indicated value is an average of three measurements. Again, $I(200)/\text{noise condition}$, measured with MS, was fulfilled.

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(Table 8)

	Bias Voltage (-V)	Arclength (mbar)	Arc current (A)	Inter-layer	Layer	x	y	Q _x	Residual Stress (GPa)	Peel life (min)
Present Invention	46 40	3.0×10^{-7}	200	TiN 0.12 μ m	(Ti,Al) _x N	0.6	0.4	5.8	1.9	18.1 min
Comparison	47 150	1.0×10^{-7}	200	TiN 0.12 μ m	(Ti,Al) _x N	0.6	0.4	0.04	4.9	5.5 min

In Fig. 1 there is shown, with linear scaling a diagram of nitrogen partial pressure versus bias voltage of the tool body as applied for reactive cathodic arc evaporation as the reactive 5 PVD deposition method used to realise the Examples which were discussed above.

All the process parameters of the cathodic arc evaporation process, namely

- arc current;
- process temperature;
- deposition rate;
- evaporated material;
- strength and configuration of magnetic field adjacent the arc source;
- 15 - geometry and dimensions of the process chamber and of the workpiece tool to be treated

were kept constant. The remaining process parameters, namely partial pressure of the reactive gas - or total pressure - and bias voltage of the tool body to be coated as a workpiece and 20 with respect to a predetermined electrical reference potential, as to the ground potential of the chamber wall, were varied.

Thereby, titanium aluminum nitride was deposited. With respect to reactive gas partial pressure and bias voltage of the tool body, different working points were established and the result-

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ing Q_i values at the deposited hard material layers were measured according to MS.

It turned out that there exists in the diagram according to fig. 1 an area P, which extends in a first approximation line-

5 arly from at least adjacent the origin of the diagram coordinates, wherein the resulting layer leads to very low XRD intensity values of $I(200)$ and $I(111)$. It is clear that for exactly determining the limits of P, a high number of measurements will have to be done. Therein, none of the $I(200)$ and 10 $I(111)$ intensity values is as large as 20 times the average noise level, measured according to MS.

On one side of this area P and as shown in fig. 1 Q_i is larger than 1, in the other area with respect to P, Q_i is lower than 1. In both these areas at least one of the values $I(200)$,

15 $I(111)$ is larger than 20 times the average noise level, measured according to MS.

As shown with the arrows in fig. 1, diminishing of the partial pressure of the reactive gas - or of the total pressure if it is practically equal to the said partial pressure - and/or in-

20 creasing of the bias voltage of the tool body being coated, leads to reduction of Q_i . Thus, the inventive method for producing a tool which comprises a tool body and a wear resistant layer system, which latter comprises at least one hard material layer, comprises the steps of reactive PVD depositing the at

25 least one hard material layer in a vacuum chamber, thereby pre-selecting process parameter values for the PVD deposition process step beside of either or both of the two process parameters, namely of partial pressure of the reactive gas and of bias voltage of the tool body. It is one of these two parame-

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ters or both which are then adjusted for realising the desired Q_i values, thus, and according to the present invention, bias voltage is reduced and/or partial reactive gas pressure is increased to get Q_i values, which are, as explained above, at

5 least larger than 1, preferably at least larger than 2 or even 5 and even better of 10. Beside the inventively exploited Q_i value, in this "left hand" area, with respect to P , $I(200)$ is larger, mostly much larger than 20 times the average noise level of intensity, measured according to MS.

10 In fig. 2 a typical intensity versus angle 2θ diagram is shown for the titanium aluminum nitride hard material layer deposited in the $Q_i \geq 1$ region according to the present invention of fig. 1, resulting in a Q_i value of 5.4. The average noise level N^* is much less than $I(200)/20$. Measurement is done according to

15 MS.

In Fig. 3 a diagram in analogy of that in fig. 2 is shown, but the titanium aluminum nitride deposition being controlled by bias voltage and nitrogen partial pressure to result in a $Q_i \leq 1$. The resulting Q_i value is 0.03. Here the $I(111)$ value is 20 larger than the average noise level of intensity, measured according to MS.

Please note that in fig. 1 the respective Q_i values in the respective regions are noted at each working point measured (according to MS).

25 In fig. 4 a diagram in analogy to that of the figs. 2 and 3 is shown for working point P_i of fig. 1. It may be seen that the intensities $I(200)$ and $I(111)$ are significantly reduced compared with those in the area outside P . None of the values

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I(200) and I(111) reaches the value of 20 times the noise average level N*.

Thus, by simply adjusting at least one of the two Q_r -controlling reactive PVD process parameters, namely of reactive gas partial pressure and of workpiece bias voltage, the inventively exploited Q_i value is controlled.

In fig. 1 there is generically shown with $\partial Q_i < 0$ the adjusting direction for lowering Q_i , and it is obvious that in opposite direction of adjusting the two controlling process parameters, 10 and increase of Q_i is reached.

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